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[TITLE OF THE INVENTION] Ink jet head, and recording apparatus and recording method using the same

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[TYPE OF THE DOCUMENT] Specification

[TITLE OF THE INVENTION] Ink jet head, and recording apparatus and recording method using the same

[CLAIMS]

[Claim 1]

An ink jet head comprising:

an ejection port plate having at least one ink ejection port;

a substrate provided apart from said ejection port plate by a predetermined distance and adapted to form an ink chamber between said substrate and said ejection port plate;

a structure inserted into said ink ejection port; and

ink ejection means for ejecting said ink,

wherein a contact angle of a surface of said structure in at least a portion existing in said ink ejection port with respect to the ink is set larger than a contact angle of an inner wall surface of said ink ejection port with respect to the ink.

[Claim 2]

The ink jet head according to Claim 1, wherein said surface of said structure in at least the portion existing in said ejection port has ink-repellent property.

[Claim 3]

The ink jet head according to Claim 1 or 2, wherein a difference between said contact angle of said surface of said structure in at least the portion existing in said ejection port with respect to the ink and said contact angle of said inner wall surface of said ejection port with respect to the ink is set at not less than 10 degrees.

[Claim 4]

The ink jet head according to any one of Claims 1 to 3, wherein said contact angle of said surface of said structure in at least the portion existing in said ejection port with

respect to the ink is set at not less than 20 degrees.

[Claim 5]

The ink jet head according to any one of Claims 1 to 4, wherein said ink contains charged fine particles which are dispersed in a solvent, and said ejection means is an ejection electrode provided on a side of said ejection port plate in said ink room.

[Claim 6]

A recording apparatus, comprising the ink jet head according to any one of Claims 1 to 5,

wherein said image is recorded on said recording medium using said ink jet head.

[Claim 7]

A recording method for recording an image on a recording medium, comprising ejecting ink in an ink chamber, which is formed between an ejection port plate having at least one ink ejection port and a substrate provided apart from the ejection port plate by a predetermined distance, through said ink ejection port, characterized in that:

the ink to be ejected is guided by a structure that is inserted into said ink ejection port and has an ink-repellent surface in at least a portion existing in said ink ejection port.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention]

The present invention pertains to a technical field related to an ink jet head that ejects ink as ink droplets (ink jet), and a recording apparatus and a recording method for recording an image on a recording medium using the ink jet head. Specifically, the present invention relates to an ink jet head requiring less energy for ink ejection, and a recording apparatus and a recording method using the ink jet

head.

[0002]

[Prior Art]

An ink jet recording apparatus records an image on a recording medium by ejecting ink containing a colorant from ejection ports as ink droplets, which then fly and impinge on the recording medium. According to an ink droplet ejection method, there are known the ink jet recording apparatuses of an electrostatic system, a bubble system, a thermal system, a piezoelectric system, and the like.

[0003]

For example, disclosed as an electrostatic ink jet recording apparatus in Patent Document 1 is an ink jet recording apparatus in which an ink guide is arranged in an ejecting port (through-hole) formed in an ejection port plate (insulating substrate) while ejection electrodes (control electrodes) are arranged around the ejection port. In the apparatus, ink droplets are ejected by means of electrostatic force generated by applying a voltage to the election electrodes.

In the apparatus, ink is guided by the ink guide provided in the ejection port and ink droplets are ejected from the tip portion so that the ink droplets can fly in a stable manner.

[0004]

Further, in Patent Document 2, an ink jet printer nozzle is disclosed in which a pin serving as an ink guide is provided inside an ejection port (nozzle) and, when an ink droplet flies out from the ejection port, a tail portion of the ink droplet is cut by an end portion (protrusion) of the pin. With this construction, an ink meniscus in the ejection port is stabilized at the time of flying of the ink droplet and cutting of the ink droplet.

Also, in Patent Document 3, a liquid injection recording head is disclosed in which a rod-like guide is provided inside an ejection port and is subjected to treatment imparting hydrophilic property thereto. With this construction, at the time of ejection of an ink (recording liquid) droplet, the ink droplet is ejected along the rod-like guide, which stabilizes an ejection direction of the ink droplet.

[0005]

In addition, in either of the case of the apparatuses described above, the ink is pulled out or pushed out through a gap with the ink guide provided in a tight space of the ejection port, so that a large force is required in order to cause ink ejection. That is, it is required to increase the pulse voltages to the ejection electrodes in the case of the electrostatic system, to increase electric power to heating elements in the case of the bubble system or the thermal system, and to increase electric power to piezoelectric elements in the case of the piezoelectric system. Consequently, there arises a problem in that loads on an electric circuit and the like are increased and operation stability is lowered.

Also, at the time of activation of the apparatuses (at the time of start of recording), a long time is taken to supply the ink to the ejection port, so that a delay time from exertion of an ejection force to actual ejection is elongated, during which it is impossible to eject an ink droplet having a predetermined size set for the ejection force. Consequently, there involves a problem in that the dot sizes of first several dots become small and a print failure occurs.

Further, in Patent Document 3, the ink guide is made ink-receptive in order to enhance a contact property of the

ink to the ink guide, which causes a problem in that the larger ejection force is necessary for ink ejection.

[0006]

[Patent Document 1]

JP 10-138493 A

[Patent Document 2]

JP 2002-273893 A

[Patent Document 3]

JP 2650944 B

[0007]

[Problems to be Solved by the Invention]

An object of the present invention is to provide an ink jet head capable of solving the above-mentioned problems inherent in the prior art, realizing energy saving while reducing an ejection force necessary for supplying ink to an ejection portion and for ejecting the ink from the ejection portion, shortening a delay time from exertion of an ejection force to ejection of an ink droplet having a correct size, preserving an ink meniscus with stability, and performing precise image recording through stabilized ink ejection, and a recording apparatus and a recording method using the same.

[0008]

[Means to Solve the Problems]

In order to solve the above-mentioned problems, the present invention provides an ink jet head, comprising: an ejection port plate having at least one ink ejection port; a substrate that is provided so as to be spaced apart from the ejection port plate by a predetermined distance and forms an ink chamber between the substrate and the ejection port plate; a structural member inserted into the ink ejection port; and ink ejection means for ejecting ink, wherein a contact angle of a surface of the structural member in at least a portion existing in the ink ejection port with

respect to the ink is set larger than a contact angle of an inner wall surface of the ink ejection port with respect to the ink.

[0009]

Preferably, the surface of the structural member in at least the portion existing in the ink ejection port is made ink-repellent.

Preferably, a difference between the contact angle of the surface of the structural member in at least the portion existing in the ink ejection port with respect to the ink and the contact angle of the inner wall surface of the ink ejection port with respect to the ink is set at 10° or larger.

Preferably, the contact angle of the surface of the structural member in at least the portion existing in the ink ejection port with respect to the ink is set at 20° or larger.

[0010]

Preferably, the structural member in at least the portion existing in the ink ejection port is configured with a ink-repellent member, and the surface of the structural member in at least the portion existing in the ink ejection port is processed with a ink repellent material.

Preferably, the tip end portion of the structural member protrudes from the ejection port plate. Preferably, the tip end portion of the structural member has an affinity for the ink.

[0011]

It is preferable that the ink comprises charged fine particles dispersed in a solvent; and the ejection means comprises an ejection electrode provided on a side of the ejection port plate in the ink chamber.

[0012]

The present invention further provides an ink jet recording apparatus, comprising the ink jet head according to

any one of the fifth aspect of the present invention, wherein the image is recorded on the recording medium using the respective ink jet head described above.

[0013]

The present invention further provides a recording method for recording an image on a recording medium, comprising ejecting ink in an ink chamber, which is formed between an ejection port plate having at least one ink ejection port and a substrate provided so as to be spaced apart from the ejection port plate by a predetermined distance, through the ink ejection port, wherein the ink to be ejected is guided by a structural member that is inserted into the ink ejection port and has an ink-repellent surface in at least a portion existing in the ink ejection port.

[0014]

[Embodiment of the Invention]

Hereinafter, an ink jet head according to the present invention, and a recording apparatus and a recording method using the ink jet head will now be described in detail based on preferred embodiments with reference to the accompanying drawings.

[0015]

FIG. 1 is a schematic cross-sectional view showing an outlined construction of the embodiment of the ink jet head of the present invention that is used in the ink jet recording apparatus of the present invention.

An ink jet head 10 shown in the drawing records an image on a recording medium in accordance with image data by ejecting ink Q containing a colorant component as ink droplets toward the recording medium using predetermined ejection means. The ink jet head 10 includes an ejection port plate 12, a substrate 14, an ink guide 16, and an ejection means 18. The ink jet head 10 further includes

partition walls 20 in accordance with a recording system adopted by the ejection means 18. The recording medium is arranged at a position (upper side in the drawing) opposing a tip end portion 16a of the ink guide 16. An ink droplet of the ink Q ejected from the tip end portion 16a flies toward the recording medium in an upward direction in the drawing and impinges on the recording medium at a predetermined position, thereby forming an image.

[0016]

It should be noted here that in the case shown in FIG. 1, only one ejection portion constituting the ink jet head 10 is conceptually illustrated. In the ink jet head 10 of the present invention, however, the number of ejection portions is not specifically limited so long as at least one ejection portion is provided. Also, no limitation is imposed on physical arrangement and the like of the ejection portions. For instance, it is also possible to construct a line head by one-dimensionally or two-dimensionally arranging multiple ejection portions. Also, by providing multiple ink jet heads 10 of the present invention whose number is equal to the number of ink colors used, it becomes possible to cope with color recording as well as monochrome recording.

[0017]

In the ejection port plate 12, multiple opening portions that each have a predetermined shape and serve as an ejection port 22 are formed at predetermined intervals. Each ejection port 22 is one independent ejection portion and the ejection means 18 is provided for each ejection portion.

The substrate 14 is provided so as to be spaced apart from the ejection port plate 12 by a predetermined distance and an ink chamber 24 is formed between the ejection port plate 12 and the substrate 14. The ink chamber 24 includes a not-shown ink supply port and ink recovery port

as necessary and is connected to a not-shown ink supply system. Also, in the ink chamber 24, the partition walls 20 that divide the ink chamber 24 into sections for respective ejection portions while maintaining a flow path of the ink Q are provided in accordance with the recording system adopted by the ejection means 18. In the illustrated case, the partition walls 20 are provided for the ejection port plate 12 and a substrate 14 side is set as the ink flow path communicating with each ejection portion.

[0018]

The ink guide 16 guides the ink Q in the ink chamber 24 to an ejection position and is provided on the substrate 14 at a position corresponding to each ejection port 22. The ink guide 16 is arranged so as to pass through substantially the center of the ejection port 22, with its tip end protruding from a surface (upper surface in the drawing) on the recording medium P side of the ejection port plate 12. In the illustrated case, the ink guide 16 is provided on the substrate 14, although the present invention is not limited to this so long as the ink guide 16 is provided in substantially the center of the ejection port 22. For instance, there may be used a form in which the ink guide 16 itself is not be provided on the substrate 14 or the like but a member for supporting the ink guide 16 is attached to the substrate 14, the ejection port plate 12, or the partition wall 20 and fixedly supports the ink guide 16.

[0019]

Also, the ink guide 16 includes an ink-repellent portion 16b in its region existing inside the ejection port 22, that is, in a region surrounded by an inner wall surface 22a of the ejection port 22. A contact angle of the surface of the ink-repellent portion 16b with respect to the ink Q is set larger than a contact angle of the inner wall surface 22a

of the ejection port 22 with respect to the ink Q. Also, the ink-repellent portion 16b has an ink-repellent surface. A preferable range of the contact angle of the ink-repellent portion 16b with respect to the ink Q will be described later.

[0020]

The ink-repellent portion 16b is made of an ink-repellent material or formed by performing surface treatment such as coating of a predetermined region of the ink guide 16 with the ink-repellent material. The ink-repellent material used to obtain the ink-repellent portion 16b is selected in accordance with the ink Q used in the ink jet head 10.

Also, when the supporting member or the like of the ink guide 16 exists inside the ejection port 22, a region of the supporting member or the like existing inside the ejection port 22 need only be constructed so as to have the same contact angle as the ink-repellent portion 16b.

[0021]

The ejection means 18 is known ejection means that causes ejection of an ink droplet of the ink Q from the ink jet head 10 and is provided for each ejection portion. When the ink jet head 10 is used in an electrostatic ink jet recording apparatus, for instance, an ejection electrode or the like is provided for each ejection port 22 as the ejection means 18. Also, in the case of a thermal or bubble-jet (registered trademark) ink jet recording apparatus, a heating element or the like is provided for each ejection portion. Further, in the case of a piezoelectric ink jet recording apparatus, a piezoelectric element or the like is provided for each ejection portion. The ejection means 18 is controlled by not-shown control means in accordance with an image to be recorded on the recording medium.

[0022]

It should be noted here that the ink jet recording

apparatus of the present invention equipped with the ink jet head 10 further includes an ink supply system that is connected to the ink jet head 10 and supplies the ink Q to the ink chamber 24 at a predetermined speed. For the above operation, the ink supply system includes an ink tank, a supply pipe that connects the ink tank to the supply port of the ink chamber 24, a pump, various measuring instruments, and the like. Also, the ink jet recording apparatus may include an ink recovery system for recovering the ink Q from the ink chamber 24 as necessary.

Plural sets of the ink jet head 10, the ink supply system, and the like are prepared in a number corresponding to the requisite number of ink colors in accordance with a recording form of the ink jet recording apparatus in which these elements are implemented.

[0023]

The ink jet head 10 having the construction described above includes a structural member in the ejection port 22, that is, the ink-repellent portion (16b) in the ink guide 16 and in the supporting member of the ink guide 16, so that it becomes possible to reduce an ejection force required to supply the ink Q to the tip end portion 16a and to eject the ink Q from the tip end portion 16a.

In the ink jet head 10, a predetermined amount of the ink Q is supplied from the ink chamber 24 to the tip end portion 16a and an ink droplet having a predetermined size is ejected from the tip end portion 16a by the ejection means 18. Here, in the ejection port 22, a narrow ink supply path from the ink chamber 24 to the tip end portion 16a is formed between the inner wall surface 22a and the ink guide 16. By providing the ink-repellent portion 16b in a region of the ink guide 16 constituting this narrow ink supply path, an ink-pulling-out resistance is reduced in the ink-repellent

portion 16b, which makes it possible to reduce a force required to pull out or push out the ink Q from the narrow ink supply path and to reduce an ejection force. Also, ink supply to the tip end portion 16a is performed swiftly, so that it becomes possible to prevent drawing failures, ejection delays, and the like due to insufficient supply of the ink Q.

[0024]

Also, the ink Q will never adhere to the ink-repellent portion 16b provided, so that an effect is achieved in that clogging of the ejection port 22 can be prevented.

[0025]

Also, in order to sufficiently reduce the ink-pulling-out resistance in the ink-repellent portion 16b, the contact angle of the ink-repellent portion 16b with respect to the ink Q is preferably set at 20° or larger, more preferably at 30° or larger.

However, if the contact angle of the ink-repellent portion 16b is increased too much, the ink Q is repelled by the ink-repellent portion 16b, which makes it impossible for the ink Q to pass through the ejection port 22 and to be supplied to the tip end portion 16a. Consequently, it is preferable that the contact angle of the ink-repellent portion 16b with respect to the ink Q is set at 90° or smaller.

[0026]

On the other hand, it is preferable that the contact angle of the inner wall surface 22a of the ejection port 22 with respect to the ink Q is set small so that it is possible to maintain a pulled-out state of the ink Q to the peripheries of the ejection portion with stability and to preserve an end portion of an ink meniscus M contacting the ejection port plate 12 even before and after ejection.

[0027]

As described above, the contact angle of the inner wall surface 22a of the ejection port 22 with respect to the ink Q is kept small, so that it becomes possible to pull out the ink Q to the ejection portion with stability and to fix the end portion of the ink meniscus M to a rim portion on the recording medium P side of the inner wall surface 22a. In addition, the contact angle of the ink-repellent portion 16b with respect to the ink Q is set larger than that of the inner wall surface 22a, so that it becomes possible to swiftly supply the ink Q to the ejection portion (tip end portion 16a) with a low ejection force each time ejection is performed.

The contact angle of the ink-repellent portion 16b with respect to the ink Q is set larger than the contact angle of the inner wall surface 22a with respect to the ink Q, as described above. Here, it is preferable that the difference between these contact angles is set at 10° or larger. As a result, it is possible to obtain the effects described above.

[0028]

It should be noted here that the ink-repellent portion 16b need only be provided in at least a region of the ink guide 16 existing inside the ejection port 22 of the ejection port plate 12. Therefore, it does not matter whether the ink-repellent portion 16b is provided only in a partial region of the ink guide 16 or in the entire region thereof. Also, the ink-repellent portion 16b may be provided so that a region of the ink guide 16 on the substrate 14 side or the tip end portion 16a side is included in the ink-repellent portion 16b. Further, the ink guide 16 may be formed using an ink-repellent material, thereby setting the whole of the ink guide 16 as the ink-repellent portion 16b. In this case, however, if the contact angle of the tip end portion 16a with

respect to the ink Q is set large, the ink Q is easily released from the tip end portion 16a, which may result in an inconvenient situation where an amount of the ink Q ejected by the ejection means 18 exceeds a predetermined amount or the ink Q is ejected at the time of non-ejection. Therefore, it is preferable that the tip end portion 16a is set as a anti-ink-repellent portion having a predetermined small contact angle with respect to the ink Q (an affinity for the ink or ink-affinitive property) instead of the ink-repellent portion 16b. With this construction, it becomes possible to hold the ink Q after a tail portion of the ink Q ejected is cut.

[0029]

With the construction described above, it becomes possible to reduce an ejection force while maintaining the ink meniscus M with stability. As a result, even if the ink Q used has a small surface tension or the distance between the inner wall surface 22a and the ink guide 16 is increased, for instance, there is prevented a situation where it is difficult to preserve the ink meniscus M and to obtain ejection stability.

[0030]

Next, an operation of the ink jet head 10 in the ink jet recording apparatus equipped with the ink jet head 10 will be described.

When an apparatus power source of this ink jet recording apparatus is turned on, supply of the ink Q to the ink chamber 22 of the ink jet head 10 is started. The ink Q is pushed out or pulled out through a tight space between the inner wall surface 22a of the ejection port 22 and the ink guide 16 (ink-repellent portion 16b), and is supplied to the tip end portion 16a of the ink guide 16. Then, the ink meniscus M is formed at the tip end portion 16a. Here,

the ink-repellent portion 16b is provided for the ink guide 16, so that even at the time of start of the recording apparatus, the ink Q is supplied to the tip end portion 16a without delay, which makes it possible to prevent drawing failures even at the time of start of recording and to perform favorable recording from the beginning.

[0031]

When the ejection means 18 is operated in accordance with an image to be recorded on a recording medium, a predetermined amount of the ink Q is supplied to the tip end portion 16a from the ink chamber 24 through the ejection port 22 and a predetermined amount of the ink Q is ejected as an ink droplet from the tip end portion 16a toward the recording medium. Here, the ink-repellent portion 16b is provided for the ink guide 16, so that a resistance force at the time of passage of the ink Q through the tight space of the ejection port 22 is suppressed. Consequently, it becomes possible to reduce an ink ejection force that needs to be applied by the ejection means 18.

[0032]

After a predetermined amount of the ink Q flies, the shape of the ink meniscus M is restored by the ink Q newly supplied. The contact angle of the inner wall surface 22a with respect to the ink Q is set small, so that there is prevented a situation where the ink Q easily slides. As a result, it becomes possible to fix an end portion of the ink meniscus M formed in proximity to the tip end portion 16a even before and after the ejection of the ink Q, which makes it possible to perform stabilized recording.

[0033]

It should be noted here that in the present invention, ink where pigments or dyes are dispersed in a solvent is used as the ink Q contained in the ink chamber 24. As the solvent,

it is possible to use various known solvents used for recording ink. Also, the pigments and dyes are not specifically limited and it is possible to use various conventionally known pigments and dyes.

[0034]

It should be noted here that in this embodiment, a case has been described in which the tip end of the ink guide 16 protrudes from the surface on the recording medium P side of the ejection port plate 12, although the present invention is not limited to this. For instance, the tip end of the ink guide 16 may be provided at a position lower than the surface of the ejection port plate 12, that is, at a position inside the ejection port 22.

Also, the position of the ink guide 16 is not limited to the form where the ink guide 16 is arranged in substantially the center of the ejection port 22 and the ink guide 16 need only be arranged at a predetermined position at which it is possible to guide the ink Q for ejection.

[0035]

Next, an example of the recording apparatus and the recording method according to the present invention will be described. An electrostatic ink jet recording apparatus and recording method using the electrostatic ink jet head according to the present invention will be described in detail with reference to FIGS. 2 and 3.

The electrostatic ink jet head records an image corresponding to image data on a recording medium by ejecting ink by means of an electrostatic force toward the recording medium held at a predetermined bias potential in a space with an ejection electrode or toward a counter electrode on the back of the recording medium through application of a predetermined voltage to each ejection electrode of the ink jet head in accordance with the image

data.

FIG. 2 is a schematic cross-sectional view showing an outlined construction of another embodiment of the ink jet head of the present invention used in the ink jet recording apparatus of the present invention, and FIG. 3 is a top view of the ink jet head 30 shown in FIG. 2 as viewed from a recording medium P side.

[0036]

An electrostatic ink jet head 30 shown in FIG. 2 records an image on a recording medium P in accordance with image data by ejecting ink Q containing an charged fine particle component like pigments (toner, for instance) by means of an electrostatic force, and includes an insulating substrate 32, a head substrate 34, an ink guide 36, an ejection electrode 38, a signal voltage source 40, and a floating conduction plate 46. Also, a counter electrode 48 for supporting the recording medium P and a charge unit 50 for charging the recording medium P are provided at a position opposing an ejection portion of the ink jet head 30.

[0037]

It should be noted here that in the example shown in FIG. 2, only one ejection electrode serving as ejection means constituting the ink jet head 30 having a multi-channel structure where multiple ejection portions are two-dimensionally arranged is conceptually illustrated. Like in the example described above, it is possible to freely select the number of ejection electrodes, physical arrangement thereof, and the like in the ink jet head 30.

[0038]

The insulating substrate 32 corresponds to the ejection port plate 12 of the ink jet head 10 shown in FIG. 1 and is made of a resin such as polyimide, ceramic, or the like. In the insulating substrate 32, multiple ejection ports 42

are formed at predetermined intervals (see FIG. 3) and the ejection electrode 38 serving as the ejection means is provided for each ejection port 42.

Also, the head substrate 34 is provided so as to be spaced apart from the insulating substrate 32 by a predetermined distance. An ink flow path 44 functioning as an ink reservoir (ink chamber) for supplying the ink Q to the ejection portion is formed between the insulating substrate 32 and the head substrate 34.

[0039]

The ink Q in the ink flow path 44 contains a fine particle component charged to the same polarity as a voltage applied to the ejection electrode 38. At the time of recording, the ink Q is circulated by a not-shown ink circulation mechanism in a predetermined direction (from the right to the left, in the illustrated case) in the ink flow path 44 at a predetermined speed (ink flow of 200 mm/s, for instance). Hereinafter, a case where the color particles in the ink are positively charged will be described as an example. Also, in the ink Q used in the ink jet head 30, Isoper (registered trademark) G is used as an ink solvent. Note that aside from this, it is possible to use various kinds of ink described below as the ink Q. The effects of the present invention are provided regardless of which kind of ink is used.

[0040]

A contact angle of an inner wall surface 42a of the ejection port 42 formed in the insulating substrate 32 made of polyimide with respect to the ink Q is set small. When Isoper (registered trademark) G or the like is used as the ink solvent like in this embodiment, it is preferable that the contact angle of the inner wall surface 42a with respect to the ink Q is set at 20° or smaller.

[0041]

The ink guide 36 includes a main body made of polyimide and an ink-repellent portion 36b made of a fluororesin. The ink guide 36 is a flat-plate-like member having a predetermined thickness and including a protrusion-like tip end portion 36a, and is arranged on the head substrate 34 at the position of each ejection port 42. The ink guide 36 passes through substantially the center of the ejection port 42 and the tip end portion 36a thereof protrudes upward from a surface on the recording medium P side of the insulating substrate 32. In the illustrated example, the ink-repellent portion 36b is provided in a region of the ink guide 36 existing inside the ejection port 42, that is, in substantially the whole of a region of the ink guide 36 surrounded by the inner wall surface 42a of the ejection port 42.

[0042]

As the fluororesin used to form the ink-repellent portion 36b, it is possible to suitably use polytetrafluoroethylene (PTFE), tetrafluoroethylene-perfluoroalkoxy ethylene copolymer (PFA), tetrafluoroethylene-hexafluoropropylene copolymer (FEP), tetrafluoroethylene-ethylene copolymer (ETFE), polychlorotrifluoroethylene (PCTFE), chlorotrifluoroethylene-ethylene copolymer (ECTFE), polyvinylidene fluoride (PVDF), polyvinyl fluoride (PVF), or the like. The ink-repellent portion 36b made of any of these materials is set so as to have a large contact angle with respect to the ink Q that is in a range of 30° to 60°.

[0043]

It should be noted here that the whole of the ink guide 36 may be made of polyimide and the ink-repellent portion 36b may be obtained by coating a predetermined region of the

ink guide 36 with an ink-repellent material. In this case, as the ink-repellent material for coating, it is possible to suitably use an ink-repellent agent that is fluorine-containing copolymer such as Sitop (registered trademark), FTP, or PFA. The ink-repellent portion 36b formed using such a material is set so as to have a large contact angle with respect to the ink Q that is in a range of 30° to 60°.

[0044]

Note that a slit serving as an ink guide groove that guides the ink Q into the tip end portion 36a by capillary action may be formed in a center portion of the ink guide 36 in a vertical direction in the drawing.

It should be noted here that the tip end portion 36a side of the ink guide 36 is formed to gradually taper into a substantially triangular shape (or a substantially trapezoidal shape) toward the counter electrode 48 side. Here, it is preferable that a metal has been vapor-deposited on the tip end portion (extreme tip end portion) 36a of the ink guide 36 from which the ink Q is to be ejected. Although it is not always necessary to carry out the metal vapor-deposition for the tip end portion 36a of the ink guide 36, it is preferable that the metal vapor-deposition is conducted because the effective dielectric constant of the tip end portion 36a of the ink guide 36 becomes large as a result of the metal vapor-deposition and an effect of easily generating a strong electric field is obtained. Also, the shape of the ink guide 36 is not specifically limited so long as it is possible to concentrate the ink Q, in particular, the charged fine particle component in the ink Q in the tip end portion 36a through the ejection port 42 in the insulating substrate 32. For instance, the shape of the tip end portion 36a may be changed as appropriate into a shape other than the protrusion, such as a conventionally known shape.

[0045]

Also, each ejection electrode 38 is arranged in a ring shape, that is, as a circular electrode on the upper surface of the insulating substrate 32 in the drawing, that is, on a surface thereof on a recording medium P side so as to surround the ejection port 42 formed in the insulating substrate 32. Each ejection electrode 38 is connected to the signal voltage source 40 that generates a pulse signal (predetermined pulse voltage) corresponding to ejection data (ejection signal) such as image data or print data. For instance, the signal voltage source 40 generates a pulse signal of 0 V at a low-voltage level and generates a pulse signal of 800 to 1000 V at a high-voltage level. The ejection electrodes 38 are two-dimensionally arranged as shown in FIG. 3.

It should be noted here that the ejection electrode 38 is not limited to the ring-like circular electrode. That is, no specific limitation is imposed on the ejection electrode 38 so long as the electrode is a surrounding electrode arranged so as to surround the outer periphery of the ink guide 36 with a distance.

[0046]

The floating conduction plate 46 is arranged below the ink flow path 44 and is electrically insulated (in high-impedance state). In the illustrated case, the floating conduction plate 46 is arranged inside the head substrate 34, although the present invention is not limited to this and the position of the floating conduction plate 46 may be changed so long as this plate 46 is arranged below the ink flow path 44. For instance, the floating conduction plate 46 may be arranged below the head substrate 34 or arranged inside the head substrate 34 on an upstream side of the ink flow path 44 with respect to the position of the ejection electrode.

At the time of recording of an image, the floating conduction plate 46 generates an induced voltage in accordance with the value of a voltage applied to the ejection electrode and causes the fine particle component in the ink Q in the ink flow path 44 to migrate to the insulating substrate 32 side and to be concentrated. Consequently, it is required that the floating conduction plate 46 is arranged on the head substrate 34 side with respect to the ink flow path 44. Also, it is preferable that the floating conduction plate 46 is arranged on an upstream side of the ink flow path 44 with respect to the position of the ejection electrode. With this floating conduction plate 46, the concentration of the charged fine particle component in an upper layer in the ink flow path 44 is increased. As a result, it becomes possible to increase the concentration of the charged fine particle component in the ink Q passing through the ejection port 42 of the insulating substrate 32 to a predetermined level, to cause the charged fine particle component to be concentrated in the tip end portion 36a of the ink guide 36, and to maintain the concentration of the charged fine particle component in the ink Q ejected as an ink droplet R at a predetermined level.

Also, the induced voltage generated by the floating conduction plate changes in accordance with the number of operating channels, so that even if a voltage to the floating conduction plate is not controlled, charged particles required for ejection is supplied, which makes it possible to prevent clogging. Note that a power source may be connected to the floating conduction plate and a predetermined voltage may be applied thereto.

[0047]

The counter electrode 48 is arranged at a position opposing the tip end portion 36a of the ink guide 36 and

includes an electrode substrate 48a and an insulation sheet 48b arranged on the lower surface of the electrode substrate 48a in the drawing, that is, on a surface thereof on the ink guide 36 side. The electrode substrate 48a is grounded. Also, the recording medium P is supported by the lower surface of the counter electrode 48 in the drawing, that is, on a surface thereof on the ink guide 36 side, in other words, on a surface of the insulation sheet 48b, and is electrostatically adsorbed on the surface. The counter electrode 48 (insulation sheet 48b) functions as a platen of the recording medium P.

Here, at least at the time of recording, the surface of the insulating sheet 48b of the counter electrode 48, that is, the recording medium P is charged by the charge unit 50 to a predetermined negative high voltage (-1.5 kV, for instance) having a polarity opposite to the high voltage (pulse voltage) applied to the ejection electrode 38. As a result of the negative charge by the charge unit 50, the recording medium P is constantly biased to the negative high voltage with respect to the ejection voltage 18 and is electrostatically adsorbed on the insulation sheet 48b of the counter electrode 48.

[0048]

Here, the charge unit 50 includes a scorotron charger 50a that charges the recording medium P to the negative high voltage, and a bias voltage source 50b that supplies the negative high voltage to the scorotron charger 50a. Note that the charge means of the charge unit 50 used in the present invention is not limited to the scorotron charger 50a and it is also possible to use various other discharge means such as a corotron charger, a solid charger, and a discharge needle.

It should be noted here that in the illustrated example,

the counter electrode 48 includes the electrode substrate 48a and the insulation sheet 48b, and the recording medium P is charged to the negative high voltage by the charge unit 50 and is electrostatically adsorbed on the surface of the insulation sheet 48b. However, the present invention is not limited to this and the counter electrode 48 may be constructed only using the electrode substrate 48a. In this case, the counter electrode 48 (electrode substrate 48a itself) is connected to a negative high-voltage bias voltage source and is constantly biased to a negative high voltage, thereby having the recording medium P electrostatically adsorbed on the surface of the counter electrode 48.

Also, the electrostatic adsorption of the recording medium P on the counter electrode 48, and the charge of the recording medium P to the negative high voltage, or the application of the negative bias high voltage to the counter electrode 48 may be performed using different negative high-voltage sources. Further, the supporting of the recording medium P by the counter electrode 48 is not limited to the electrostatic adsorption of the recording medium P and another supporting method or supporting means may be used.

[0049]

Because of the two-dimensional arrangement as shown in FIG. 3, the ink jet head 30 may have a guard electrode for suppressing an electric filed interference that may occur between adjacent ejection electrodes. This guard electrode needs only to be arranged between the adjacent ejection electrodes 38, on the same surface as the ejection electrodes 38 or on the recording medium P side thereof so as to shield against other electric fields than those required for the respective ejection portions.

[0050]

In the ink jet head 30 constructed in the manner described above, the ink Q is supplied to the tip end portion 36a from the ink flow path 44 by passing through the ejection port 42 and forms an ink meniscus M at the tip end portion 36a by means of an electrostatic field generated between the proximity of the tip end portion 36a and the negatively charged recording medium P. Here, the ink-repellent portion 36b is provided in the region of the ink guide 36 inside the ejection port 42, so that the ink Q passes through the ejection port 42 speedily and is supplied to the tip end portion 36a swiftly. Then, in proximity to the tip end portion 36a, the positively charged color fine particles in the ink Q are concentrated by means of the electrostatic force.

[0051]

When a predetermined positive voltage is applied to the ejection electrode 38 by the signal voltage source 40 in accordance with an image, the ink Q where the positively charged fine particles are concentrated at the tip end portion 36a is ejected as an ink droplet R having a predetermined size, is attracted by the recording medium P, and impinges on the recording medium P at a predetermined position. In this manner, a dot of an image is formed on the recording medium P. Here, the ink-repellent portion 36b is provided as described above, so that it becomes possible to reduce a force required to pull out the ink Q to the tip end portion 36a from the ink flow path 44, which makes it possible to reduce a force required to eject the ink droplet R, that is, a voltage applied to the ejection electrode 38. Also, the inner wall surface 42a of the ejection port 42 preserves the end portion of the ink meniscus M even before and after ejection, so that it becomes possible to maintain the size of the ink droplet R and the shape of the

ink meniscus M with stability, which makes it possible to perform stabilized recording.

[0052]

Here, the inventor of the present invention measured the recording performance of the ink jet head 30 of the present invention by performing actual recording using an electrostatic ink jet recording apparatus that uses the electrostatic ink jet head 30 described in the present invention.

In the electrostatic ink jet head 30 shown in FIG. 2, the diameter of the ejection port 42 was set at 130 μm. Also, the ink guide 36 having a thickness (depth in the drawing) of 75 μm and a width of 75 μm was arranged at substantially the center of the ejection port 42, with the tip end thereof protruding from the surface of the insulating substrate 32 by 150 μm. The ejection electrodes 38 were each a circular electrode having an inside diameter of 150 μm and an external diameter of 250 μm, and were arranged on a surface on the recording medium P side of the insulating substrate 32 so as to be substantially concentric with the respective ejection ports 42. Ink produced by dispersing positively charged fine particle component in a solvent (Isoper (registered trademark) G) was used as the ink Q and was circulated in the ink flow path 44 at a flow rate of around 200 mm/s. Also, the counter electrode 48 was arranged so that the recording medium P was spaced apart from the tip end of the ink guide 36 by 500 μm. The recording medium P was negatively charged by the charge unit 50 and a voltage applied to the ejection electrode 38 was changed in a range of 800 to 1000 V.

Also, the insulating substrate 32 was made of polyimide and the contact angle of the inner wall surface 42a of the ejection port 42 with respect to the ink Q was set at 5°.

Further, the ink guide 36 was made of polyimide and the ink-repellent portion 36b was provided for the whole of a region of the ink guide 36 surrounded by the inner wall surface 42a of the ejection port 42. This ink-repellent portion 36b was formed by coating the surrounded region with Sitop (registered trademark) and the contact angle of the surface thereof with respect to the ink Q was set larger than the contact angle of the inner wall surface 42a by 35°, that is, was set at 40°.

[0053]

A pulse voltage required for ink ejection in the recording apparatus equipped with this ink jet head 30 was measured. In the case of an ink jet head where the ink guide 36 was not provided with the ink-repellent portion 36b and a contact angle of the whole of the ink guide 36 was set at 5°, in order to eject the ink droplet R, it was required to apply a pulse voltage of 1000 V and a bias voltage of -1.5 kV to the ejection electrode 38. On the other hand, in the case of the ink jet head 30 of the present invention provided with the ink-repellent portion 36b, the pulse voltage and bias voltage required for ejection were reduced to 800 V and -1.3 kV, respectively.

[0054]

Also, in the case of the ink jet head using the ink guide 36 without the ink-repellent portion 36b, at the time of image drawing at 5 kHz, dot sizes of the first three dots from the start of recording were reduced. On the other hand, in the case of the ink jet head 30 of this embodiment provided with the ink-repellent portion 36b, it was possible to perform drawing with a predetermined dot size from the first dot.

[0055]

Note that the electrostatic ink jet head 30 as

described above has the ejection electrodes 38 such as the circular electrodes arranged on the upper surface of the insulating substrate 32 in the drawing as a mono-layered electrode structure. However, this is not the sole case of the present invention and the ejection electrodes 38 may be arranged on the upper and lower surfaces of the insulating substrate 32 as a two-layered electrode structure.

FIG. 4(a) and FIG. 4(b) schematically show an electrostatic inkjet head 60 having ejection electrodes of a two-layered electrode structure according to still another preferred embodiment of the present invention. Note that the inkjet head 60 shown in these drawings has the same construction as the ink jet head 30 shown in FIG. 2 except that the inkjet head 60 shown in FIG. 4(a) and FIG. 4(b) includes second drive electrodes 62 provided on the lower surface of the insulating substrate 32 in the drawings, an insulation layer 66a provided below the second drive electrodes 62 as well as an insulating layer 66b, a guard electrode 64 and an insulation layer 66c provided in this order above the ejection electrodes (first drive electrodes) 38 arranged on the upper surface of the insulating substrate 32 in the drawings. Therefore, the same construction elements are given the same reference numerals and the description thereof is omitted in this embodiment. That is, differences will be mainly described in this embodiment.

[0056]

The inkjet head 60 shown in FIG. 4(a) adopts the two-layered electrode structure in which the ejection electrodes 38 include the ejection electrodes arranged as the first drive electrodes on the upper surface of the insulating substrate 32 in the drawing (these ejection electrodes being hereinafter referred to as the "first drive electrodes") 38 and the second drive electrodes 62 arranged on the lower

surface of the insulating substrate 32 in the drawing. The first drive electrodes 38 and the second drive electrodes 62 are circular electrodes arranged in the respective ejection portions in a ring shape on the upper surface and the lower surface of the insulating substrate 32 so as to surround through holes 68 formed in the insulating substrate 32. The inkjet head 60 also includes the insulation layer 66a covering the lower side (lower surface) of the second drive electrodes 62, the sheet-like guard electrode 64 arranged above the first drive electrodes 38 with the insulation layer 66b in-between, and the insulation layer 66c covering the upper surface of the guard electrode 64. As shown in FIG. 4(b), the multiple first drive electrodes 38 are connected to each other in a row direction (main scanning direction) and the multiple second drive electrodes 62 are connected to each other in a column direction (sub-scanning direction).

[0057]

The through holes 68 are formed so as to also pass through the insulation layer 66a below the insulating substrate 32 and the insulation layers 66b and 66c above the insulating substrate 32. That is, the through holes 68 are formed so as to pass through a layered product of the insulation layer 66a, the insulating substrate 32, and the insulation layers 66b and 66c. Ink guides 36 are inserted into the through holes 68 from an insulation layer 66a side so that tip end portions 36a of the ink guides 36 protrude from the insulation layer 66c. Note that in the illustrated example, no ink guide groove is formed in the tip end portions 36a of the ink guides 36, but ink guide grooves may be formed in order to promote concentration of the ink Q and the charged fine particle component in the ink Q to the tip end portions 36a. The ink-repellent portion 36b is provided in the portion of the ink guide 36 corresponding to the

inside of the through hole 68.

[0058]

The guard electrode 64 is arranged between the first drive electrodes 38 of adjacent ejection portions and suppresses electric field interferences occurring between the ink guides 36 in adjacent ejection portions. The guard electrode 64 is arranged on the recording medium P side of the ejection electrodes 38 in a predetermined region between adjacent ejection electrodes 38 so as to shield against other electric field than those required for the respective ejection portions.

[0059]

In this preferred embodiment, at the time of recording, the first drive electrodes 38 are sequentially set at a high-voltage level or under a high-impedance state (ON state) for each row and all of the other first drive electrodes 38 are driven to a ground level (ground state: OFF state). Also, all second drive electrodes 62 are driven to a high-voltage level or a ground level on a column basis in accordance with the image data. Note that as a modification to the preferred embodiment, the first and second drive electrodes 38 and 62 may be driven in a reversed manner.

[0060]

As shown in FIG 4, the first and second drive electrodes 38 and 62 are arranged in a matrix manner so as to form the two-layered electrode structure. By the first and second drive electrodes 38 and 62, ink ejection/non-ejection at respective ejection portions is controlled. That is, when the first drive electrodes 38 are set at the high-voltage level or under a floating state and the second drive electrodes 62 are set at the high-voltage level, the ink will be ejected. When one of the first drive electrodes 38 and the second drive electrodes 62 are set at the ground level,

the ink will not be ejected.

[0061]

FIG. 4(b) is a conceptual diagram showing an exemplary arrangement of the first and second drive electrodes 38 and 62. As shown in this drawing, when the inkjet head 60 includes 15 ejection electrodes (individual electrodes), for instance, five individual electrodes (1, 2, 3, 4, and 5) are arranged on each row in the main scanning direction and three individual electrodes (A, B, and C) are arranged on each column in the sub-scanning direction. At the time of recording, the five first drive electrodes 38 arranged on the same row are simultaneously driven to the same voltage level. In the same manner, the three second drive electrodes 62 arranged on the same column are simultaneously driven to the same voltage level.

[0062]

Accordingly, in the electrostatic ink jet head 60 of this preferred embodiment, it is possible to arrange multiple individual electrodes in a two-dimensional manner with respect to the row direction and the column direction.

In the case of the ink jet head shown in FIG. 4(b), for instance, the five individual electrodes (first drive electrodes 38) on the row A are arranged at predetermined intervals with respect to the row direction. The same applies to the row B and the row C. Also, the five individual electrodes on the row B are spaced apart from the row A by a predetermined distance in the column direction and are respectively arranged between the five individual electrodes on the row A and the five individual electrodes on the row C with respect to the row direction. In the same manner, the five individual electrodes on the row C are spaced apart from the row B by a predetermined distance in the column direction and are respectively arranged between

the five drive electrodes on the row B and the five drive electrodes on the row A with respect to the row direction.

[0063]

In this manner, the individual electrodes (first drive electrodes 38) on each row are arranged so as to be displaced from the individual electrodes on other rows in the row direction. With this arrangement, one line to be recorded on the recording medium P is divided into three groups in the row direction.

That is, one line to be recorded on the recording medium P is divided into multiple groups, whose number is equal to the number of rows of the first drive electrodes 38 with respect to the row direction and sequential recording is performed in a time-division manner. In the case of the example shown in FIG. 4(b), for instance, sequential recording is performed for the rows A, B, and C of the first drive electrodes 38, thereby recording one line of an image on the recording medium P. In this case, as described above, one line to be recorded on the recording medium P is divided into three groups in the row direction and sequential recording is performed in a time-division manner.

[0064]

An outlined construction of an electrostatic ink jet head 60 shown in FIG. 4 will be further described with reference to FIGS. 5, 6(a), and 6(b). FIG. 5 is a schematic perspective view of an example of the ink jet head of this preferred embodiment, FIG. 6(a) is a schematic cross-sectional view of the ink jet head shown in FIG. 5, and FIG. 6(b) is the arrow view taken along the line VII-VII of FIG. 6(a).

[0065]

In this preferred embodiment, the guard electrode 64 is

a sheet-like electrode, such as a metal plate, that is common among all ejection electrodes, and holes are formed in the guard electrode 64 in portions corresponding to the first drive electrodes 38 formed around the through holes 68 for respective ejection electrodes two-dimensionally arranged (see FIGS. 6(a) and 6(b)).

[0066]

By the way, the upper side of the guard electrode 64 in the drawings is covered with the insulation layer 66c except for the through holes 68 and the insulation layer 66b is disposed between the guard electrode 64 and the first drive electrodes 68, thereby insulating the electrodes 64 and 38 from each other. That is, the guard electrode 64 is arranged between the insulation layer 66c and the insulation layer 66b and the first drive electrodes 38 are arranged between the insulation layer 66b and the insulating substrate 32.

That is, as shown in FIG. 7(b), on the upper surface of the insulating substrate 32, that is, between the insulation layer 66b and the insulating substrate 32 (see FIG. 6), the first drive electrodes 38 formed around the through holes 68 for the respective ejection portions are two-dimensionally arranged and the multiple first drive electrodes 38 are connected to each other in the column direction.

[0067]

Also, as shown in FIG. 7(c), on the upper surface of the insulation layer 66a and on the lower surface of the insulating substrate 32, that is, between the insulation layer 66a and the insulating substrate 32 (see FIG. 6), the second drive electrodes 62 formed around the through holes 68 for the respective ejection electrodes are two-dimensionally arranged and multiple second drive electrodes 62 are connected to each other in the row direction.

Further, in this preferred embodiment, in order to

shield a repulsive electric field from the ejection electrode (drive electrode) 18 of each ejection electrode, from the first and second drive electrodes 38 and 62, for instance, toward the ink flow path 44, a shield electrode may be provided on a flow path side with respect to the first and second drive electrodes 38 and 62.

[0068]

As described above, the first and second drive electrodes 38 and 62 are arranged in a matrix manner so as to form the two-layered electrode structure. By the first and second drive electrodes 38 and 62, ink ejection/non-ejection at respective ejection portions is controlled. That is, when the first drive electrodes 38 are driven on a row basis to be set at the high-voltage level or under a floating state and the second drive electrodes 62 are driven on a column basis in accordance with image data to be set at the high-voltage level, the ink will be ejected from the ejection portions. When one of the first drive electrodes 38 and the second drive electrodes 62 are set at the ground level, the ink will not be ejected.

[0069]

It should be noted here that in this embodiment, pulse voltages may be applied to the first and second drive electrodes 38 and 62 in accordance with image signals and the ink ejection may be performed when both of these electrodes are set at the high-voltage level.

For instance, in an ink jet head 60 shown in FIG. 8, when a fine particle component in the ink Q is positively (+) charged, that is, when the ink Q contains positively charged particles, for instance, an electric field with which the ink Q is circulated in a direction of the arrow "a" in an ink flow path 44 of the ink jet head 60 and the positively charged particles in the ink Q (ink droplet) ejected from a

tip end portion 36a of an ink guide 36 of an ejection portion are attracted by a recording medium P, that is, a flying electric field is formed between the first and second drive electrodes 38 and 62 and the recording medium P. A distance (gap) between the tip end portion 36a of the ink guide 36 and the recording medium P is set in a range of 200 to 1000 μm, for instance. When the gap is set at 500 μm, the flying electric field is formed by providing a potential difference in a range of 1 kV to 2.5 kV.

Also, by an average voltage applied to the first or second drive voltage 38 or 62, an induced voltage that is lower than the average voltage is almost constantly generated in a floating conduction plate 46, so that an electric field (hereinafter referred to as the "migration electric field", for instance) is formed with which the positively charged particles in the ink Q in the ink flow path 44 functioning as an ink reservoir are attracted upward and the positively charged particles in the ink Q gather in the upper portion of the ink flow path 44. By providing a potential difference of around several hundred V with respect to a thickness of the ink flow path 44 of several mm, for instance, the migration electric field is formed.

[0070]

For instance, in the ink jet head 60 shown in FIG. 8, the recording medium P is charged to a predetermined negative high voltage (or a counter electrode 48 is biased to a predetermined high voltage) and the first and second drive electrodes 38 and 62 are both set at 0 V (ground state), thereby forming the flying electric field. Then, the guard electrode 64 is set at 0 V (ground state).

Under this state, the ink Q moves upward from the ink flow path 44 to a space between the through hole 68 and the ink guide 36 and gathers in the tip end portion 36a by

electrophoretic action and capillary action. The ink Q gathering in the tip end portion 36a is retained by the tip end portion 36a or by the surface tension or the like of the ink Q and the concentration of the positively charged particles in the ink Q is increased to a high level.

[0071]

Next, as shown in FIG. 9, pulse voltages are applied to the first and second drive electrodes 38 and 62 in accordance with an image signal and an ink droplet R having highly concentrated positively charged particles is ejected from the tip end portion 36a of the ink guide 36. For instance, when the initial particle concentration is in a range of 3 to 15%, it is preferable that the particle concentration in the ejected ink droplet R is 30% or higher. Note that the pulse widths of the pulse voltages are not specifically limited, but it is possible to set the pulse widths in the range of several tens of μs to several hundred μs, for instance. Also, the sizes of dots recorded on the recording medium P depend on the magnitudes or application time lengths of the pulse voltages, so that it is possible to adjust the dot sizes by adjusting the pulse voltage magnitudes or application time lengths.

[0072]

Here, in the ink jet head 60 of the present invention, the ink guide 36 is provided with the ink-repellent portion 36b, so that it is possible to reduce a charge voltage value of the recording medium P (or a bias voltage value of the counter electrode 48) required to suitably eject the ink droplet R as compared with the case of the ink guide without the ink-repellent portion 36b. For instance, in the case of the ink guide without the ink-repellent portion 36b, it was required to set the bias voltage at -1.5 kV. However, by providing the ink-repellent portion 36b, it was possible to

reduce the bias voltage to −1.3 kV.

Also, with the ink-repellent portion 36b, it becomes possible to reduce the pulse voltages applied to the first and second drive electrodes 38 and 62. For instance, in the case of the ink guide without the ink-repellent portion 36b, it was required to apply a pulse voltage of 500 V to each of the first and second drive electrodes 38 and 62. However, with the ink-repellent portion 36b, it was possible to suitably perform ink ejection even if each pulse voltage was reduced to 400 V.

[0073]

It should be noted here that in the ink jet head 60 of this preferred embodiment, it is not specifically limited whether the ink ejection/non-ejection is controlled using one or both of the first drive electrodes 38 and the second drive electrodes 62. However, it is preferable that the ejection of the ink Q is not performed when one of the first drive electrodes 38 and the second drive electrodes 62 are set at the ground level and the ink ejection is performed only when the first drive electrodes 38 are set under the high-impedance state or at the high-voltage level and the second drive electrodes 62 are set at the high-voltage level.

[0074]

By the way, as in the illustrated example, the guard electrode 64 is provided between adjacent first drive electrodes 38 in the ink jet head 60 of this embodiment, but the present invention is not limited to this. For instance, when the first and second drive electrodes 38 and 62 are matrix-driven, that is, when the second drive electrodes 62 of the lower layer are sequentially driven in units of columns and the first drive electrodes 38 of the upper layer are driven in accordance with image data, the guard electrode may be provided only in spaces between the rows of

the first drive electrodes 38. Even in this case, by biasing the guard electrode 64 to a predetermined guard potential (ground level, for instance) at the time of recording, it becomes possible to eliminate the influence of adjacent ejection portions.

[0075]

Also, when the rows of the first drive electrodes 38 of the upper layer are sequentially turned on and the second drive electrodes 62 of the lower layer are turned on/off in accordance with image data at the time of driving of the ejection electrodes 38, that is, when the arrangement of the rows and columns is interchanged, the second drive electrodes 62 are driven in accordance with the image data. Therefore, the ejection electrodes on both sides of each ejection electrode in the column direction are frequently switched between the high-voltage level and the ground level.

In the row direction, however, the first drive electrodes 38 are driven in units of rows and the first drive electrodes 38 of the ejection electrodes on both sides of a currently driven row are constantly set at the ground level. Consequently, the rows of the ejection electrodes on the both sides play the role of a guard electrode. As described above, when each row of the first drive electrodes 38 of the upper layer are sequentially turned on and the second drive electrodes 62 of the lower layer are driven in accordance with image data, it becomes possible to eliminate the influence of adjacent ejection electrodes and to improve recording quality without providing a guard electrode.

[0076]

Further, in the ink jet head 60 according to this embodiment, the floating conduction plate 46 is provided which constitutes the undersurface of the ink flow path 44 and causes the positively charged ink particles (charged

particles, that is, charged fine particle component) in the ink flow path 44 to migrate upwardly (that is, toward the recording medium P side) by means of induced voltages generated by pulse-like ejection voltages applied to the first drive electrodes 38 and the second ejection electrodes 44. Also, an electrically insulative coating film (not shown) is formed on a surface of the floating conduction plate 46, thereby preventing a situation where the physical properties and components of the ink are destabilized due to charge injection into the ink or the like. It is preferable that the electric resistance of the insulative coating film is set at 10^{12} Ω·cm or higher, more preferably at 10^{13} Ω·cm or higher. Also, it is preferable that the insulative coating film is corrosion resistant to the ink, thereby preventing a situation where the floating conduction plate 46 is corroded by the ink. Further, the floating conduction plate 46 is covered with an insulation member from its bottom side. With this construction, the floating conduction plate 46 is completely electrically insulated and floated.

Here, at least one floating conduction plate 46 is provided for each head (that is, in the heads for C, M, Y, and K, each head is provided with at least one floating conduction plate and the heads for C and M will never share the same floating conduction plate).

[0077]

In the respective embodiments of the electrostatic ink jet heads having the ejection electrodes of the two-layered electrode structure as described above, the counter electrode (recording medium P) may be charged to -2.1 kV, for instance, and the ink ejection may be controlled so that the ink will not be ejected when at least one of the first drive electrodes and the second drive electrodes are set at a negative high voltage (-400 V, for instance) and the ink

will be ejected only when both of the first drive electrodes and the second drive electrodes are set at the ground level (0V).

[0078]

In the respective embodiments described above, the shape of the ejection electrodes 38 (first drive electrode 38, second drive electrode 62) are not limited to be circular but the ejection electrodes 38 may have each a substantially circular shape or a divided circular shape. Alternatively, the ejection electrodes 38 may also be parallel or substantially parallel electrodes.

[0079]

It should be noted that in an embodiment of an electrostatic ink jet head according to the present invention, in addition to those mentioned above, the ink Q which may be used to supply to the ink flow path 44 may include the ink that contains charged color particles (charged color fine particle component) whose particle size is around 0.1 to 5 μm and which are dispersed in a carrier liquid. Note that dispersion resin particles for improving fixability of an image after printing may be contained in the ink as appropriate together with the charged color particles. It is preferable that the carrier liquid is a dielectric liquid (non-aqueous solvent) having a high electric resistivity (at least 10^9 Ω·cm, preferably 10^{10} Ω·cm or higher, and preferably 10^{16} Ω·cm or lower). If a carrier liquid having a high electric resistivity is used, it is possible to limit the carrier liquid charged by charge injection by the voltages applied from the ejection electrodes, so that it becomes easier to increase charged particles (charged fine particle component) in concentration and therefore charged particles are condensed. Also, the carrier liquid having a high electric resistivity can prevent from occurring electrical

continuity between adjacent recording electrodes. Further, using the ink made of the liquid having such a high electric resistivity enables satisfactory ink ejection in a low electric field.

[0080]

It is preferable that the relative permittivity of the dielectric liquid used as the carrier liquid is 5 or lower, more preferably 4 or lower, and still more preferably 3.5 or lower. It is preferable that the lower limit value of the relative permittivity thereof is around 1.9. By setting the relative permittivity in such a range, an electric field effectively acts on the charged particles in the dielectric liquid and migration easily occurs. As a result, it is possible to suppress polarization of the solvent and electric field relaxation and to obtain dots with satisfactory image density but less bleeding.

[0081]

In preferred embodiments of the electrostatic ink jet head according to the present invention, the dielectric liquid to be used include straight-chain or branched aliphatic hydrocarbons, alicylic hydrocarbons, aromatic hydrocarbons, or halogen substituents of the hydrocarbons. For example, hexane, heptane, octane, isooctane, decane, isodecane, decalin, nonane, dodecane, isododecane, cyclohexane, cyclooctane, cyclodecane, benzene, toluene, xylene, mesitylene, Isopar C, Isopar E, Isopar G, Isopar H, Isopar L (Isopar: a trade name of EXXON Corporation), Shellsol 70, Shellsol 71 (Shellsol: a trade name of Shell Oil Company), AMSCO OMS, AMSCO 460 Solvent, (AMSCO: a trade name of American Mineral Spirits Company), a silicone oil (such as KF-96L, manufactured by Shin-Etsu Silicones), etc. may be used singly or as a mixture of those.

[0082]

As to the color particles dispersed in the dielectric liquid (non-aqueous solvent), a colorant itself or the colorant contained in dispersion resin particles for improving fixability may be used. In the latter case, the color particles with pigments or the like are generally formed as resin-coated particles by coating pigments or the like with the resin material of the dispersion resin particles, or the color particles with dyes or the like are generally obtained as color particles by coloring the dispersion resin particles with dyes. As the colorant, it is possible to use any of pigments and dyes conventionally used in an ink jet ink composition, a printing (oil-based) ink composition, and an electro-photographic liquid developer.

[0083]

The ink particles dispersed in the ink, in other words color particles (fine particles) preferably contains resin (particles) and colorant (particles).

Here, in terms of printed image density, forming uniform dispersion, and suppressing clogging of the ink in the ejection head, the content of the ink particles (total content of the color particles and/or the resin particles) dispersed in the ink is preferably in a range of 0.5 to 30 wt% based on the total weight of the ink, more preferably in a range of 1.5 to 25 wt%, and still more preferably in a range of 3 to 20 wt%.

[0084]

Pigments to be used as colorants may be inorganic pigments or organic pigments commonly employed in the field of printing technology. Specific examples thereof include, but are not particularly limited to, well-known pigments such as Carbon Black, Cadmium Red, Molybdenum Red, Chrome Yellow, Cadmium Yellow, Titanium Yellow, chromium oxide, Viridian, Cobalt Green, Ultramarine Blue, Prussian Blue, Cobalt Blue,

azo pigments, phthalocyanine pigments, quinacridone pigments, isoindolinone pigments, dioxazine pigments, threne pigments, perylene pigments, perinone pigments, thioindigo pigments, quinophthalone pigments, and metal complex pigments.

[0085]

Preferred examples of dyes to be used as colorants include oil-soluble dyes such as azo dyes, metal complex salt dyes, naphthol dyes, anthraquinone dyes, indigo dyes, carbonium dyes, quinoneimine dyes, xanthene dyes, aniline dyes, quinoline dyes, nitro dyes, nitroso dyes, benzoquinone dyes, naphthoquinone dyes, phthalocyanine dyes, and metal phthalocyanine dyes.

[0086]

Also, the average particle size of the ink particles, such as the color particles and/or resin particles, dispersed in the dielectric solvent is preferably in a range of 0.1 μm to 5 μm, more preferably in a range of 0.2 μm to 1.5 μm, and still more preferably in a range of 0.4 μm to 1.0 μm. The particle size was obtained using CAPA-500 (manufactured by HORIBA, Ltd.).

[0087]

Here, it is preferable that the ink particles (dispersion resin particles and/or color particles or colorant particles) in the ink Q are positively or negatively charged particles.

It is possible to impart charge to the ink particles by appropriately using a technique of electro-photographic developer. In more detail, it is possible to impart the charge to the ink particles using charge detection agent and/or other additives described in "Latest Systems for Electro-photographic Development, and Development and Application of Toner Materials" (pp. 139 to 148), "Fundamentals and Applications of Electro-photographic

Techniques" (edited by Electro-photographic Society, pp. 497 to 505, CORONA PUBLISHING CO., LTD., 1988), "Electro-photography" (Yuji Harasaki, Vol. 16 (No.2), p. 44, 1977), and the like.

[0088]

Further, the viscosity of the ink composition is preferably in a range of 0.5 to 5 mPa·s, more preferably in a range of 0.6 to 3.0 mPa·s, and still more preferably in a range of 0.7 to 2.0 mPa·s. The color particles have electric charges and it is possible to use various charge control materials used for electro-photographic liquid developer as necessary. The charge amount thereof is preferably in a range of 5 to 200 μC/g, more preferably in a range of 10 to 150 μC/g, and still more preferably in a range of 15 to 100 μC/g. Also, there is a case where the electric resistance of the dielectric solvent changes due to addition of the charge control material. The charge detection agent is added so that the distribution factor P defined below becomes preferably 50% or higher, more preferably 60% or higher, and still more preferably 70% or higher.

$P=100\times(\sigma 1-\sigma 2)/\sigma 1$

Here, $\sigma 1$ is the electric conductivity of the ink composition and $\sigma 2$ is the electric conductivity of a supernatant of the ink composition obtained with a centrifugal separator. The electric conductivity is a value measured using an LCR meter (AG-4311 manufactured by Ando Electric Co., Ltd.) and an electrode for liquid (LP-05 manufactured by Kawaguchi Electric Works Co., Ltd.) by applying a voltage of 5 V at a frequency of 1 kHz. Also, the centrifugation was performed using a high speed refrigerated microcentrifuge (SRX-201 manufactured by TOMY SEIKO CO., LTD.) for 30 minutes at a rotation speed of 14500 rpm under a temperature of 23°C.

With the ink composition described above, migration of the charged particles easily occurs and concentration is facilitated.

[0089]

On the other hand, the electric conductivity σ1 of the ink composition is preferably in a range of 100 to 3000 pS/cm, more preferably in a range of 150 to 2500 pS/cm, and still more preferably in a range of 200 to 2000 pS/cm. By setting the electric conductivity in this range, voltages applied to the ejection electrodes are prevented from becoming extremely high and therefore there is eliminated apprehension that electrical breakdown or continuity may occur between adjacent ejection electrodes. Also, the surface tension of the ink composition is preferably in a range of 15 to 50 mN/m, more preferably in a range of 15.5 to 45 mN/m, and still more preferably in a range of 16 to 40 mN/m. By setting the surface tension in this range, the voltages applied to the ejection electrodes are prevented from becoming extremely high and therefore there is prevented a situation where the head is soiled with ink leaking and spreading around the head.

[0090]

In an embodiment of an electrostatic ink jet head according to the present invention, instead of causing the ink to fly toward a recording medium by applying a force to the whole of the ink as in the conventional ink jet procedures, the charged fine particle component (charged toner particles) that is a solid component dispersed in the carrier liquid mainly receives a force and is caused to fly toward the recording medium. As a result, it becomes possible to record an image on various recording media, such as a nonabsorbable film like a PET film, as well as plain paper. Also, it becomes possible to obtain an image having

high image quality on various recording media by preventing blurring or flowing of the ink on the recording media.

[0091]

Also, in the embodiment described above, an ink jet recording apparatus has been described which performs image recording using ink ejected by positively charging color particles in ink and setting a recording medium or a counter electrode on the back surface of the recording medium at a negative high voltage. However, the present invention is not limited to this and may be applied to an apparatus that performs image recording using ink ejected by negatively charging color particles in ink and setting a recording medium or a counter electrode at a positive high voltage. When the polarity of the charged color particles are set opposite to that in the embodiments described above in this manner, the polarities of voltages applied to the electrostatic adsorption means, the counter electrode, and the drive electrodes of the electrostatic ink jet head and the like are set opposite to those in the embodiments described above.

[0092]

Further, preferred embodiments of the electrostatic ink jet head and the recording apparatus according to the present invention are not limited to the case where ink containing a charged colorant component is ejected. There is no particular limitation as far as the present invention is applied to a liquid ejection head that ejects liquid containing charged particles. For instance, in addition to the electrostatic ink jet recording apparatus as described above, the present invention can be applied to an application apparatus that applies liquid by ejecting droplets using charged particles.

[0093]

The ink jet head, and the recording apparatus and the recording method using the ink jet head according to the present invention have been described in detail above with reference to various embodiments, although the present invention is not limited to the embodiments described above. That is, it is of course possible to make various modifications and changes without departing from the gist of the present invention.

[0094]

[Effects of the Invention]

As described above in detail, according to the present invention, it becomes possible to provide an ink jet head that is capable of achieving energy saving by reducing an ejection force required to supply ink to an ejection portion and to eject the ink from the ejection portion, shortening a delay time from exertion of an ejection force to ejection of an ink droplet having a correct size, preserving an ink meniscus with stability, and performing precise image recording through stabilized ink ejection. Also, it becomes possible to provide a recording apparatus and a recording method using the ink jet head.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1] This is a schematic cross-sectional view showing an outlined construction of an embodiment of an ink jet head according to the present invention.

[FIG. 2] This is a schematic cross-sectional view showing an outlined construction of another embodiment of an ink jet head according to the present invention.

[FIG. 3] This is a top view of the ink jet head in FIG. 2.

[FIG. 4] (a) is a schematic perspective view showing an outlined construction of another embodiment of the ejection electrode of the electrostatic ink jet head according to the

present invention; and (b) is a schematic perspective view showing arrangement of first and second drive electrodes used as the individual electrode shown in (a).

[FIG. 5] This is a schematic perspective view showing an outlined construction of another embodiment of the electrostatic ink jet head according to the present invention.

[FIG. 6] (a) is a schematic cross-sectional view showing an outlined construction of the ink jet head shown in FIG. 5; and (b) is a cross-sectional view taken along a line VII-VII in (a).

[FIG. 7] (a), (b), and (c) are arrow views taken along lines A-A, B-B and C-C of Fig. 6(b), respectively.

[FIG. 8] This is a conceptual diagram illustrating an operation of the ink jet head shown in FIG. 5.

[FIG. 9] This is a conceptual diagram illustrating a recording operation of the ink jet head shown in FIG. 5.

[Legend]

10, 30, 60 ink jet head
12 ejection port plate
14 substrate
16, 36 ink guide
16a, 36a tip end portion
16b, 36b ink-repellent portion
18 ejection means
20 partition wall
22, 42 ejection port
22a, 42a inner wall surface
24 ink chamber
32 insulating substrate
34 head substrate
38 ejection electrode
40 signal voltage source
44 ink flow path

46 floating conduction plate

48 counter electrode

50 charge unit

62 second drive electrode

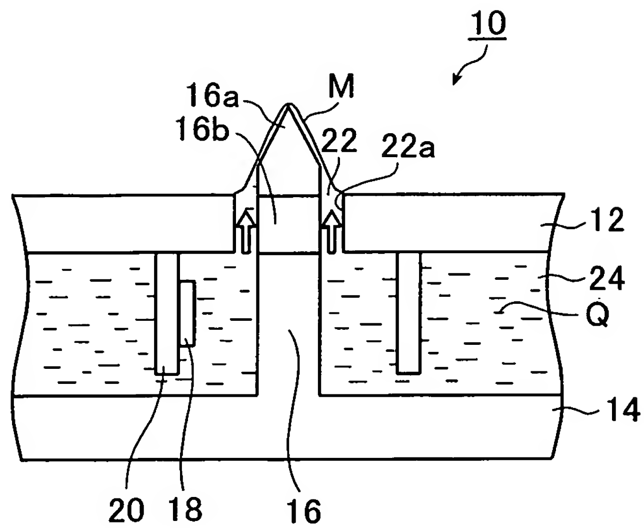
64 guard electrode

66a, 66b, 66c insulation layer

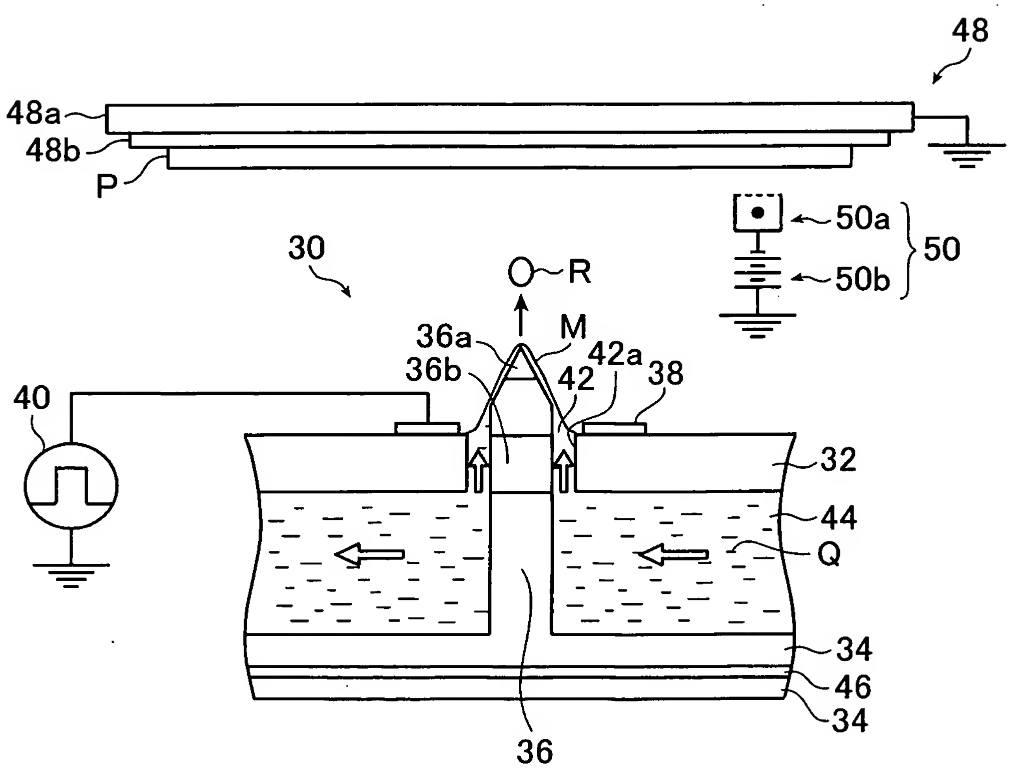
68 through hole

【TYPE OF THE DOCUMENT】 Drawings

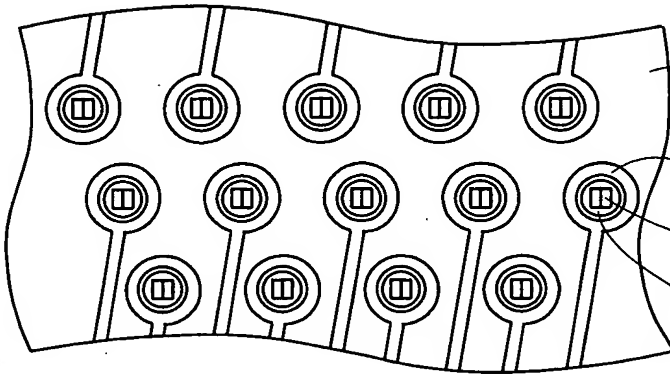
【FIG. 1】



【FIG. 2】

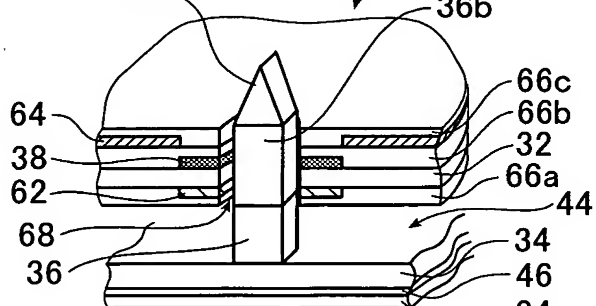


【FIG. 3】

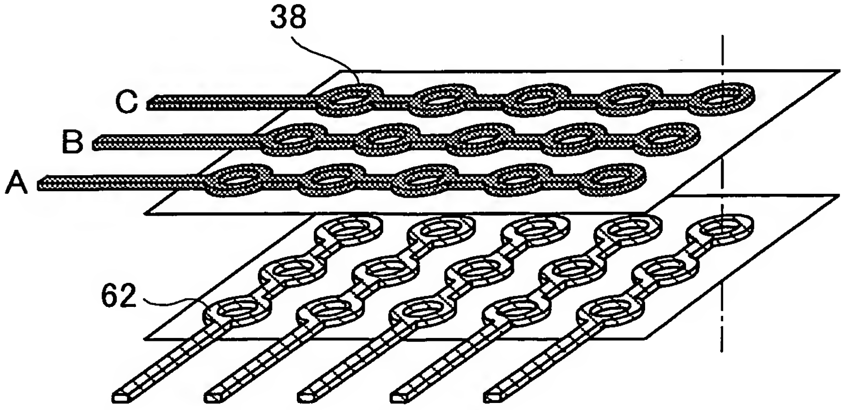

32
38
36
42

【FIG. 4】

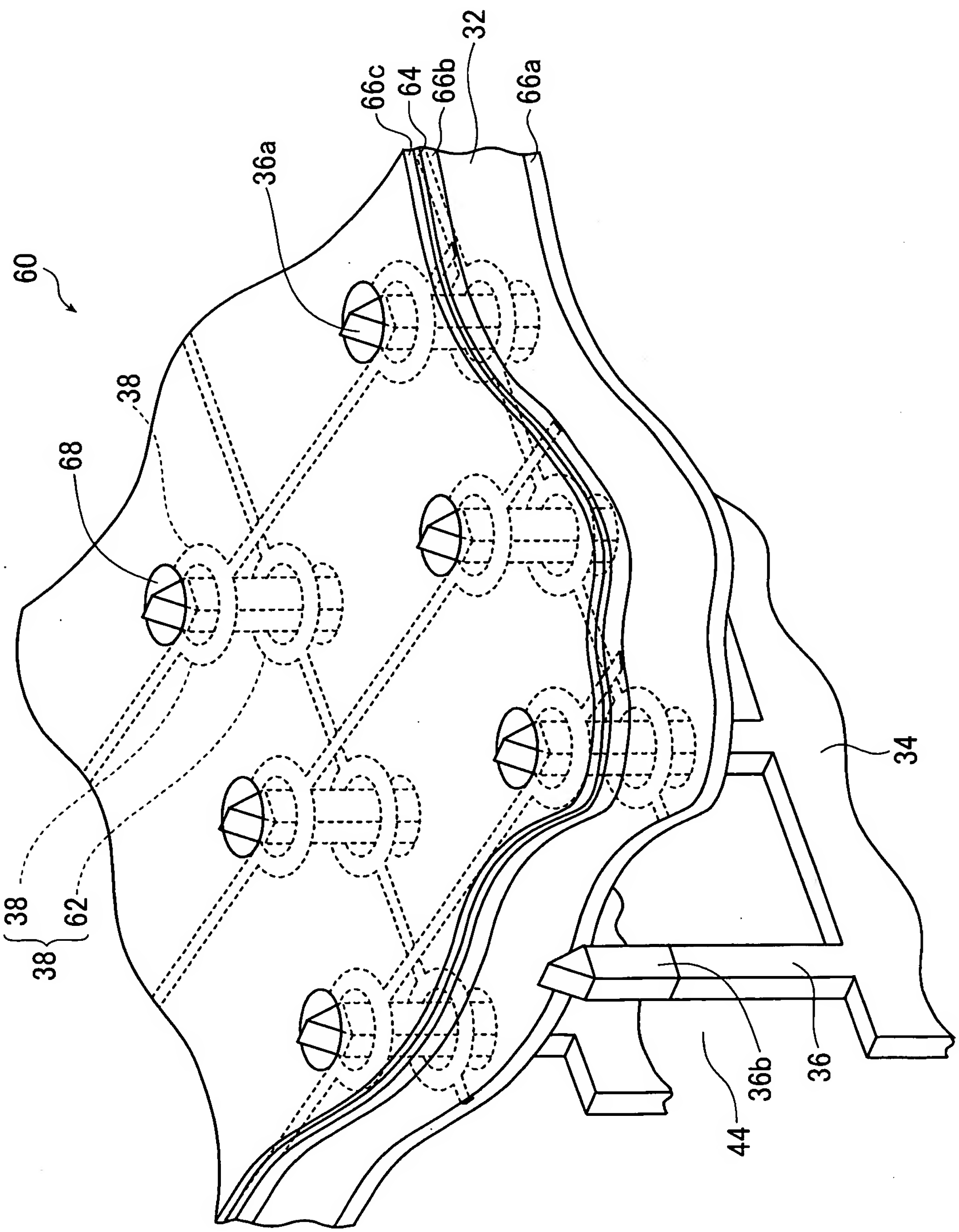
(a)


60
36a
36b
64
38
62
68
36
66c
66b
32
66a
44
34
46
34

(b)

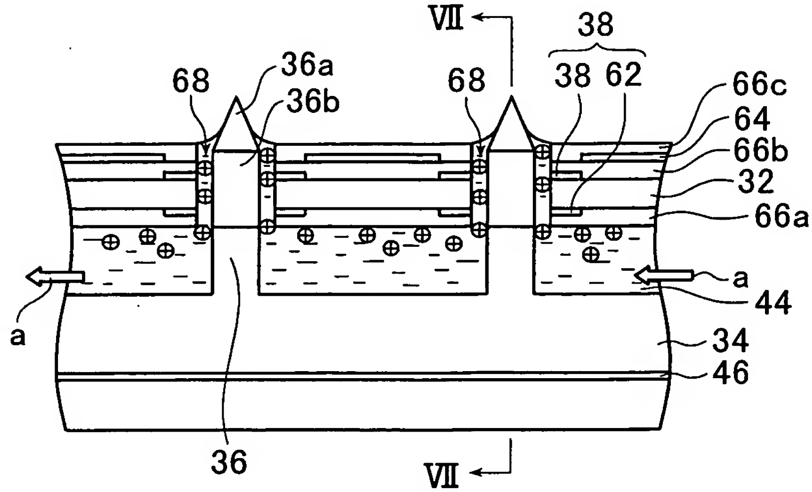

38
C
B
A
62
1
2
3
4
5

【FIG. 5】

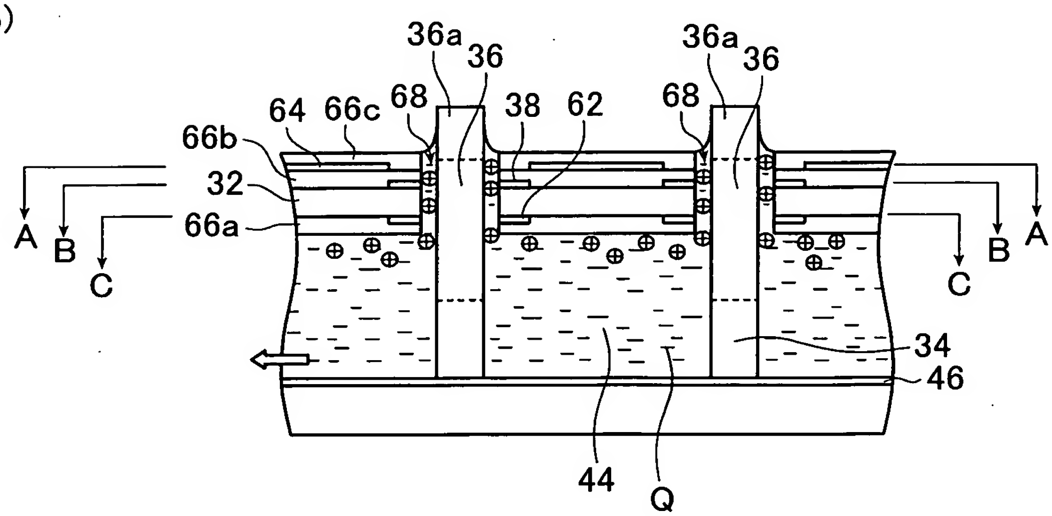


【FIG. 6】

(a)


VII
38
68
36a
36b
68
38 62
66c
64
66b
32
66a
a
44
a
34
46
36
VII

(b)


36a
36
36a
36
64
66c
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68
66b
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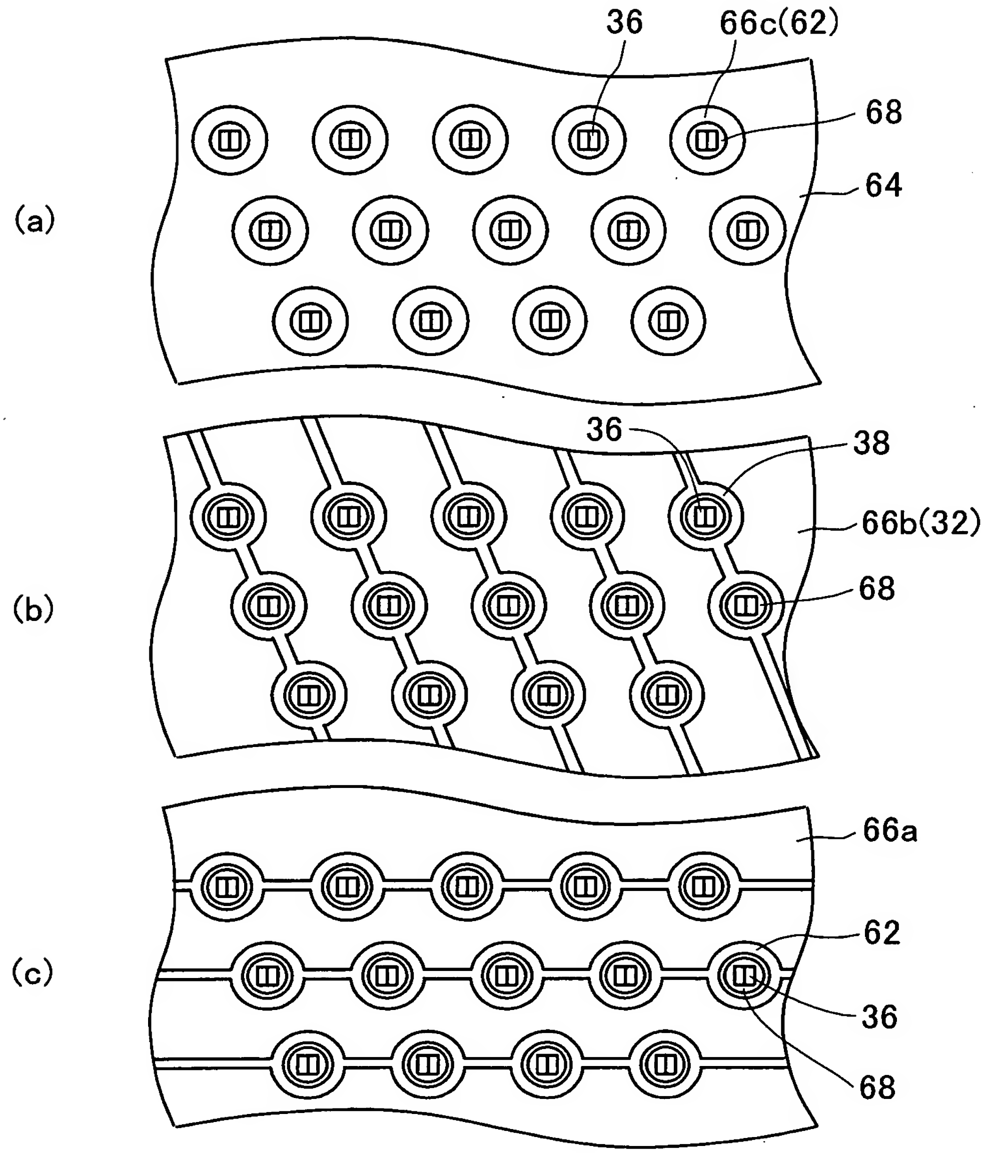
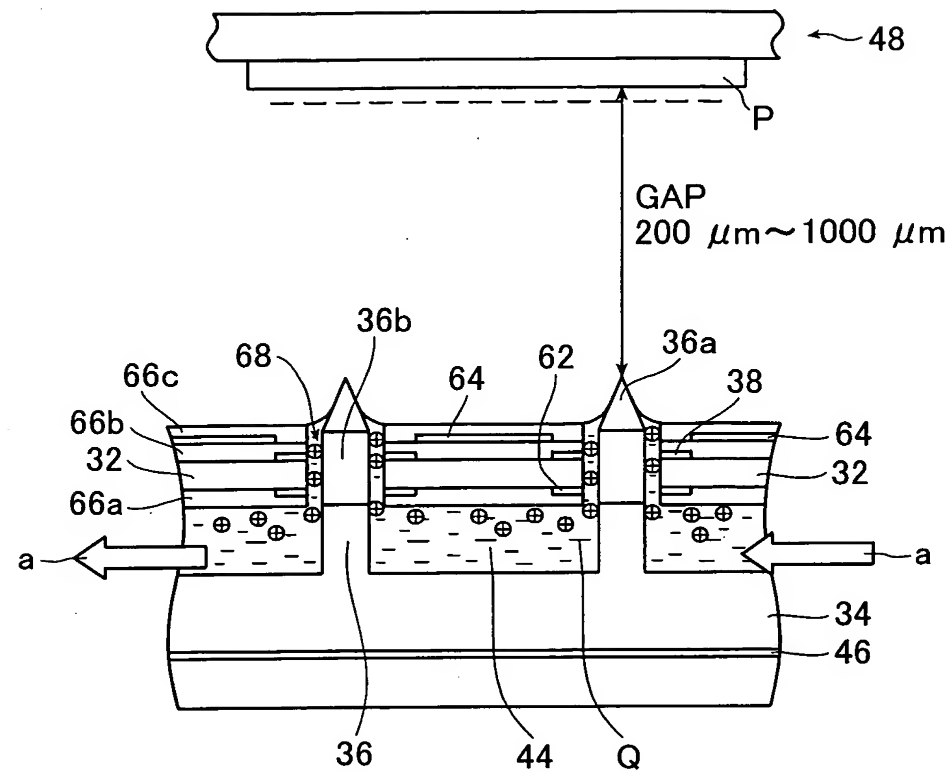
66a
A
B
C
A
B
C
34
46
44
Q

【FIG. 7】



【FIG. 8】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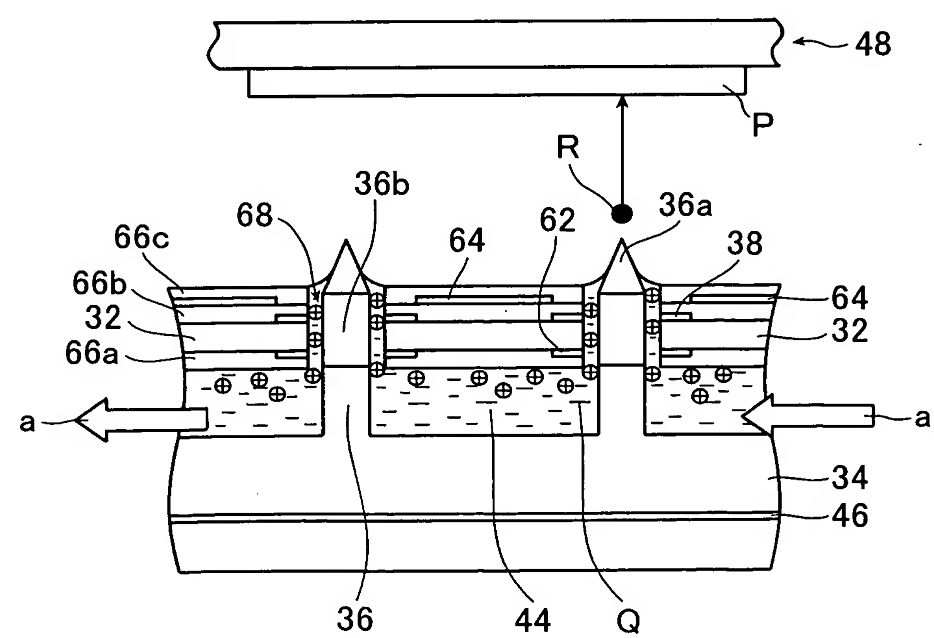
P
GAP
200 μm～1000 μm
36b
68
64
62
36a
38
66c
66b
32
66a
64
32
a
a
34
46
36
44
Q

【FIG. 9】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P
R
36b
36a
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66c
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66b
32
66a
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32
a
a
34
46
36
44
Q

[TYPE OF DOCUMENT] Abstract

[ABSTRACT]

[Subject] To provide an ink jet head capable of reducing an ejection force necessary for supplying ink to an ejection portion and for ejecting the ink from the ejection portion, shortening a delay time from exertion of an ejection force to ejection of an ink droplet having a correct size, preserving an ink meniscus with stability, and performing precise image recording through stabilized ink ejection, and a recording apparatus and a recording method using the same.

[Means for Solution] An ink jet head includes: an ejection port plate having at least one ink ejection port; a substrate provided apart from the ejection port plate by a predetermined distance and adapted to form an ink chamber between the substrate and the ejection port plate; a structure inserted into the ink ejection port; and ink ejection means for ejecting ink, in which a contact angle of a surface of the structure in at least a portion existing in the ink ejection port with respect to the ink is set larger than a contact angle of an inner wall surface of the ink ejection port with respect to the ink. Consequently, the above-mentioned object is attained.

[Selected Drawing] FIG. 1